

Appendix I

Assessment Protocol for Great Lakes Sources

August 17, 2000

Introduction

Recently there has been concern over the protection of the nation's drinking water sources. This issue has been debated nationally and eventually was addressed in federal legislation. In 1996 when the federal Safe Drinking Water Act was reauthorized, legislation was added that requires source water assessments be performed on all sources of public drinking water supplies. The assessments must consider the vulnerability of these public drinking water sources. Assessments of intakes that extend into the Great Lakes present a unique challenge in determining the scope and magnitude of these assessments with limited resources. The intakes for some of these sources extend far enough into a lake to receive no effects from specific shoreline contaminant sources (except possibly air borne contaminants) while others closer to shore do. To provide guidance on how source water assessments should be performed it will be necessary to address this very basic premise. USEPA may be able to give some assistance by providing access to data bases, developing screening methods and areawide monitoring for general contaminants, general lake responses to airborne contaminants, and other areawide general assistance.

A workgroup from the Great Lakes States has been organized to develop these parameters. This workgroup includes representatives of the Great Lakes States, water utilities with intakes on the Great Lakes, USEPA Region V, and other interested parties. There should be consensus among the states and USEPA on the make up of the group. USEPA and the Region V states met on June 16, 1999, to develop a mission statement and a final draft of this protocol. The Region V states concurred on the protocol at a workgroup meeting on August 17, 2000. The following mission statement defined the intent of the workgroup.

The mission of the Great Lakes Protocol Workgroup is to develop a consensus amongst the states for a consistent procedure allowing the flexibility necessary to properly conduct source water assessments of our Great Lakes drinking water sources. This flexibility will take into account the variability of these sources and site specific concerns for determination of source sensitivity and susceptibility.

Initial Survey

An initial survey will be performed at each Great Lakes source to assess local source water impacts. Any criteria or studies that were performed to locate the intake should be reviewed. Senior operators and the plant superintendent at the treatment plant plus other local officials should be interviewed to gain knowledge of the raw water quality fluctuations. Past water quality records from files or existing data bases would need to be reviewed and also any data collected through the Information Collection Rule (ICR). Bacteriological quality, alkalinity, and turbidity levels are good indicators of localized impacts. If this review indicates that only minor fluctuations occur in raw water quality compared to the lake's background quality, the source is probably not impacted from localized contaminants and the assessment would parallel a general water quality assessment of the total lake with some consideration for potential emergency spills.

The "Great Lakes Surface Water Assessment Survey" form developed with this protocol can be utilized as a screening tool to assist in determining localized impacts. The initial survey should be used to assist with determining procedures to follow in conducting the survey. The assessment procedures will depend upon the type of local impacts, the availability and quality of local data, weather conditions, runoff, etc.

Critical Assessment Zone

To provide some continuity for assessing the Great Lakes intakes, the concept of a "Critical Assessment Zone" (CAZ) around each intake was developed. The two factors used for this zone, which effect the sensitivity of Great Lakes intakes, are the perpendicular distance from shore or length of the intake pipeline (L) in feet and the water depth (D) of the intake structure in feet. The shallower, near shore intakes are more sensitive to shoreline influences than the off shore, deep intakes. The factor for sensitivity (S) can be calculated by the formula:

$$L \times D = S$$

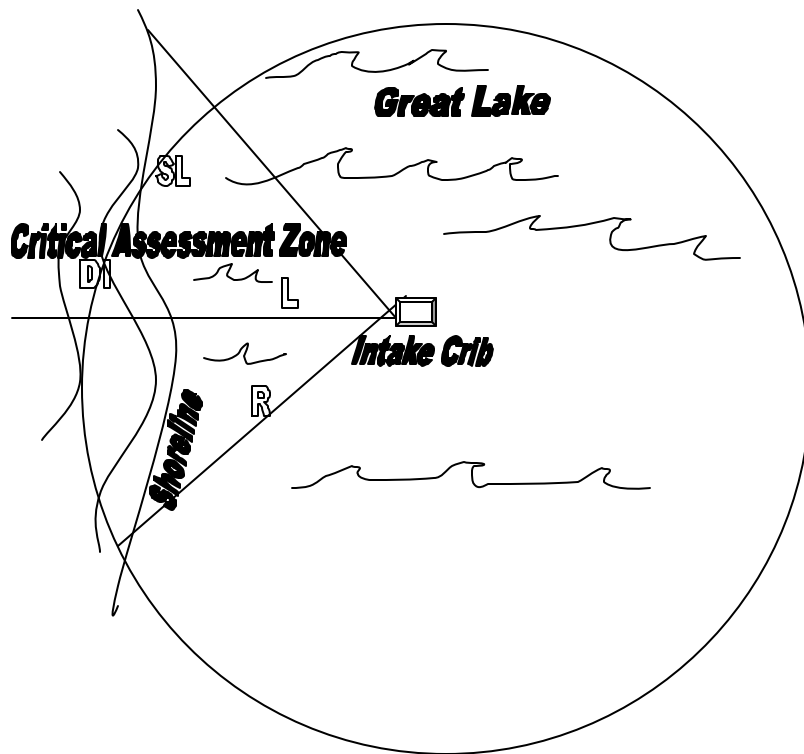
Generally, S values less than 25,000 represent highly sensitive intakes while S values greater than 125,000 indicate lower sensitivities. This degree of sensitivity can be used by the states as a tool to prioritize assessment activities and assist with the susceptibility determination after taking contaminant sources into account.

The intake's degree of sensitivity combined with information obtained from the survey form and local data such as intake construction, lake bottom characteristics, localized flow patterns, thermal effects and benthic nepheloid layers can be used to complete a sensitivity analysis. The benthic nepheloid layer is a zone of suspended sediment kept suspended by the interactions of current and sedimentation. The layer's characteristics around an intake depend on sediment density, water temperature, bottom currents, and animal activity.

The following columns represent Great Lakes intakes with high, medium, and low sensitivities. A CAZ is defined as the area from the intake structure to the shoreline and inland. This area includes a triangular water surface and a land area encompassed by an arc from the endpoint of the shoreline distance on either side of the on shore intake pipe location. The shoreline distance (SL) is measured in feet in both directions from the intake pipe location on shore while the distance inland (DI) in feet is determined by subtracting the submerged intake pipe length (L) from the critical assessment zone radius (R). The drawing, which follows, illustrates an example of the Critical Assessment Zone.

Note: v indicates square root of parenthesized calculations.

<u>Sensitivity Value</u>	<u>Critical Assessment Zone</u>	<u>Shoreline Distance</u>	<u>Distance Inland</u>
<25,000	3,000 foot radius	$SL = \sqrt{3000^2 - L^2}$	$DI = 3000 - L$
25,000-125,000	2,000 foot radius	$SL = \sqrt{2000^2 - L^2}$ $L > 2000; SL = 0$	$DI = 2000 - L$ $L > 2000; DI = 0$
>125,000	1,000 foot radius	$SL = \sqrt{1000^2 - L^2}$ $L > 1000; SL = 0$	$DI = 1000 - L$ $L > 1000; DI = 0$



Along with the sensitivity analysis, an initial inventory should be completed by a combination of a simple survey form followed by an on site interview.

Attached to this document is a survey form the states could use to conduct this interview.

Completing the Assessment

If the assessment indicates the intake is not impacted by potential shoreline contaminants, the assessment should reference general Great Lakes water quality and trends within the source water assessment area. This information has been compiled by several sources such as the USEPA's Great Lakes National Program Office (GLNPO) and the Great Lakes Mass Balance Studies done by the USEPA, the states, and the USGS. GLNPO has conducted water and sediment modeling activities using National Oceanic and Atmospheric Administration 5 kilometer grids that should be useful for modeling potential spill scenarios, from sources such as pipelines, and for assessing tributary impacts. Another source could be the Remedial Action Plans for Great Lake Areas of Concern and the Lakewide Management Plans. Some of these sources address contaminants brought forth by air deposition. Total Maximum Daily Loads (TMDLs) should also be referenced if available.

For systems where the initial survey indicates a potential for shoreline impacts, the assessment becomes more difficult and site specific. The next step would be to provide a delineation of the area that contributes potential impacts through the use of local data and/or the CAZ concept. It would then be necessary to assess the impacts in the area and their relative impact on the quality and treatability of the raw water. If a river or stream that discharges into the lake near the intake causes a significant impact, a partial watershed assessment of that river or stream would be necessary. These impacts may not be continual, but may arise only as a result of certain events such as a specific wind direction and intensity, or a river or stream discharge into the lake at a certain flow level. The USEPA BASINS software and USGS SPARROW software may provide data for this determination. There may also be impacts from certain thermal or seasonal conditions. These issues are site specific and will require extensive review of the water quality records and in depth interviews with plant personnel.

If the water quality impact is due more to a general lake condition, such as proximity to a shallow bay, wind direction, or localized current patterns, the degree of these impacts must be assessed. Interviews with the plant personnel, with extensive experience at the plant, would be essential. Once the impacts are categorized, assessments must be made for each impact. For example, if a shallow bay causes water quality impacts, these impacts should be noted along with the change in water quality anticipated and the degree and frequency of change. If the quality change results from an algae bloom, the conditions that promote the bloom should be listed, along with the resulting water

quality changes and the degree and frequency of the changes. Each impact should be listed in the narrative portion of the assessment.

If the impact results from a discharge on the shoreline, runoff from the shoreline, local tributary or location of a facility near the intake, these potential impacts should be listed and assessed. It may be necessary to delineate an additional area extending beyond the CAZ, determine the impacts in this area and then assess these impacts. This could become complex depending upon the shoreline assessment. If the impact were from runoff, it would first have to be assessed to determine the degree of impact due to the volume and concentration of contaminants in the runoff. Is the runoff significant? If it were, the potential makeup of the runoff would need to be assessed. For example, is the runoff from farmland? If so, the time of the year would be critical. If it were urban runoff, the types of commercial and industrial establishments in the area would be important. These assessments will be complex and must be designed so they can be altered and expanded, as more information becomes available. The assessment must be dynamic in nature and be designed to be expanded in the future.

Many bays and tributary mouths in urban or industrialized areas hold deposits of sediment contaminated by metals and organic toxicants. Records of EPA and state environmental management agencies, as well as the U.S. Army Corps of Engineers Harbor Dredging Programs should be evaluated to determine whether an increase in turbidity due to material suspended in such sites might pose a risk.

Wind direction, thermal effects, and local current patterns affect many intakes. The affects may be due to a shallow bay, or proximity to a shallow bay, where the bottom sediments are resuspended into the intake water column or it may direct shoreline runoff over the intake. These impacts can be surveyed by delineating an additional area that contributes water to the general area and checking the potential contaminants in the area. Extensive interviews with plant personnel and review of historical records will be necessary. Once the impact has been determined, the assessment of the impact must be made.

Remote sensing, including aerial photography and satellite imagery, can be extremely revealing both in analyzing a history of events and near real time tracking of tributary and near shore phenomena. Three-dimensional hydraulic models can be valuable tools for use in areas where they have been developed.

To complete the assessment, the susceptibility determination should include a general map of the area, the sensitivity analysis, delineation of the contributing areas, and listing of the locations of the various contaminant sources.

Before public release of the completed assessment, it should be reviewed with the water supplier for agreement of its contents.

Spill Assessments

Large volumes of materials are transported on the Great Lakes by shipping. Some of these materials are toxic in nature and are subject to accidental spillage during transit and loading. Ships also pose potential risks to intakes through accidental spills of fuel and lubricants. When doing vulnerability assessments of the intakes, this traffic should be considered. If ships pass in close proximity to an intake, or if there is a nearby commercial loading facility or harbor, procedures should be established by the water supplier to react to spills from these ships. It would not be possible to predict many specific contaminants from general shipping, but proximity of a particular industry serviced at a local harbor would indicate heightened risk potentials for specific products or supplies. Procedures could be developed for reaction to families of contaminants, such as volatile organic chemicals, pesticides, etc. Previous spills in the vicinity, if any, should be reviewed and assessed. The water supplier should have a contingency plan for guidance in an emergency.

Spills along lakeshores or connecting river shorelines should also be assessed along with potential spills from pipelines, docking facilities, railroad lines, etc. For example, there are numerous chemical plants along the St. Clair River, which connects Lake Huron to Lake St. Clair. These potential sites should first be identified and located on a map if the initial survey indicates there may be impacts from these areas. Procedures then should be developed for assessing and reacting to these types of emergencies. Where possible on the connecting rivers, modeling of the river flows could be used to assess potential impacts on intakes. In these cases, the specific contaminant would normally be known and this information could be used in the assessment.

For intakes located close to the lake shore lines, again the areas that could significantly impact the intake should be delineated. Potential spill sources in these areas such as industries; disposal facilities, highways, railroads; pipelines, etc., should be located, mapped and assessed. Depending upon the type of potential risk, the specific contaminant may be identifiable, but this may not always be the case. These spills should be considered differently from the routine discharges that may exist. A spill is a unique event, and emergency reaction would be necessary to deal with the potential impact.

Surveys of fixed facilities, pipelines, highway and rail corridors, and shipping routes have generally been completed and may be obtained by contacting the local emergency planning committee or the area planning committee. These two groups should have inventories of oil and hazardous materials at fixed facilities and along transportation routes.

The impacts from treatments at the intake should also be included in the assessments. Continual treatment for zebra mussels may cause development of other impacts on the finished water quality. Short-term treatments or impacts such as intake cleaning, dredging, construction, etc., should also be included in the assessment.

Summary

An outline of the general methodology to be used for Great Lakes intakes should be a main part of the source water assessment program for states in the Great Lakes Region. Due to the unique nature of each intake, each assessment will be site specific. Assessments of the Great Lakes water quality in general have been done by various agencies and these efforts should be referenced not duplicated. The site-specific assessments, if done in close cooperation with the treatment plants and local surface water protection agencies, become valuable tools to future operations and planning.



A Two-Dimensional, Transient Flow Model of the St. Clair – Detroit River Waterway

A Cooperative Program of the Michigan Department of Environmental Quality, Detroit Water and Sewerage Division, U.S. Geological Survey, U.S. Army Corps of Engineers, and National Oceanic and Atmospheric Administration

Flow simulations will provide a basis for understanding the effects of dredging on flow and sediment transport; predicting the movement of discharges from combined sewer overflows, tributaries, treatment plants, and spills; identifying source areas for public water supply intakes; and analyzing lake circulation patterns affecting critical habitats.

St. Clair River, Lake St. Clair, and Detroit River form part of the international boundary between the United States and Canada. This waterway is major navigational and recreational resource of the Great Lakes region that connects Lake Huron with Lake Erie. A mathematical model of flow in the St. Clair – Detroit River waterway is being developed to help assess the susceptibility of public water-supply intakes to contaminants and to better understand the water-quality characteristics and sediment movements in the waterway.

St. Clair River extends about 39 mi (miles) from its head at the outlet of Lake Huron near Port Huron, Michigan, to an extensive delta area.



Through its length, water-surface elevations fall about 5 ft (feet) as it discharges an average of 182,000 ft³/s (cubic feet per second) from a drainage area of 222,400 mi² (square miles). Lake St. Clair receives water

from St. Clair River, and lesser amounts from Clinton River in Michigan and Thames River in Ontario. Along the 25-ft deep navigational channel, the lake has a length of about 35 mi. The lake's round shape, with a surface area of 430 mi², and shallow depths that average about 11 ft, make it highly susceptible to winds and water-level changes in the connecting channels. Detroit River receives water from Lake St. Clair, where it courses 32 mi to Lake Erie. Water levels fall about 3 ft though Detroit River, which has an average discharge of 186,000 ft³/s.

The mathematical model is being developed to compute stream velocities and water-surface elevations (stage) within the waterway. The model is based on the physics of fluid flow and the geometry of the system. Flow resistance and mixing characteristics will be inferred from direct measurements of flow and stage.

Computations are driven by continuously changing stage data at the upstream and downstream limits of the waterway

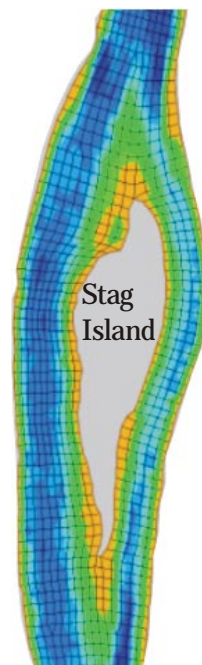
and by available wind information. When completed, the model will provide detailed information on the horizontal (vertically averaged) variations of flow and stage throughout a wide range of hydraulic conditions.

The Michigan Department of Environmental Quality recognized the need for a model as part of the Source Water Assessment Program (SWAP). This program's responsibilities include evaluation of the susceptibility of public water supply intakes to contaminants. The St. Clair-Detroit River waterway contains 13 intakes that supply water to about one third of the residents of Michigan. The Detroit Water and Sewerage Department also is supporting the development of the model because of their interest in maintaining and improving the water quality in Detroit River.

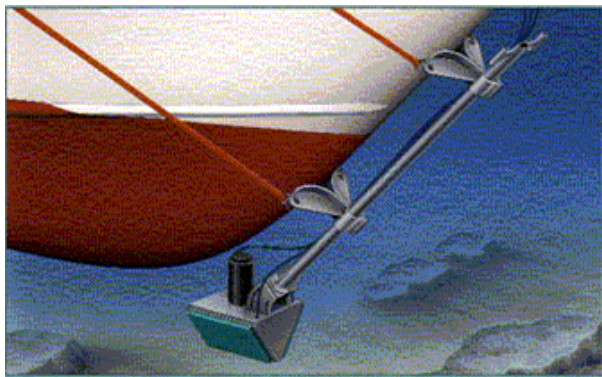
Technical development of a model was initiated in 1998 through a cooperative agreement between the MDEQ, U.S. Geological Survey (USGS) and the Detroit District, U.S. Army Corps of Engineers (USACE). The model is based on a prototype created by the Waterway Experiment Station of USACE in Vicksburg, Mississippi for the Detroit District. The prototype uses an open-source non-proprietary hydrodynamic numerical model for computations, which is referred to as RMA2.

The RMA2 code is a finite-element formulation that is widely used for far-field hydrodynamic problems in which vertical accelerations of flow are negligible and averaged vertical velocities are needed. Detroit District and Environment Canada have recently adapted the prototype to meet the special needs associated with investigating potential effects of channel encroachments on water levels on Lake St. Clair and Lake Huron.

Model development to support the SWAP also requires several major refinements of the prototype. First, the density of the finite-element grid was increased throughout the waterway to provide more detail on flow paths in the vicinity of water-supply intakes. To illustrate the grid density, part of the model for St. Clair River near Stag Island is shown to the right. In the image, shallow areas in the channel are depicted in yellow and deeper areas are depicted in blue.



Second, a new bathymetry (streambed elevation) survey is planned for the summer of 2000 within the connecting channels. The bathymetry of the prototype is based on a 1955 hydrographic survey. This survey, however, preceded a 2-ft deepening of the navigational channel in 1962. The National Oceanic and Atmospheric Administration (NOAA) is scheduled to conduct the hydrographic survey using a single-beam echo sounder, (as depicted in the image below), according to International Hydrographic Organization Chart accuracy standards. Approximately 1139 cross sections will be collected at a 100-meter line spacing. The new bathymetry data will be available by September of 2000 to more accurately describe the current flow geometry.



Finally, a formal parameter estimation analysis will be conducted to quantify the reliability of flow simulation results. This analysis will utilize a series of Acoustic Doppler Current Profile (ADCP) velocity measurements and corresponding stage data. The Detroit Office of the USACE has obtained a series ADCP measurements at numerous locations within the St. Clair and Detroit Rivers.

Measurement sets have been obtained at about 6-week intervals during the open-water periods since 1996. Each set contains about 7,000 point measurements of flow velocity. Together with stage data, the velocity measurements will allow estimation of the magnitude and uncertainty of model parameters describing flow resistance and mixing characteristics. Possible seasonal variability of model parameters, perhaps caused by aquatic growth, will be analyzed.

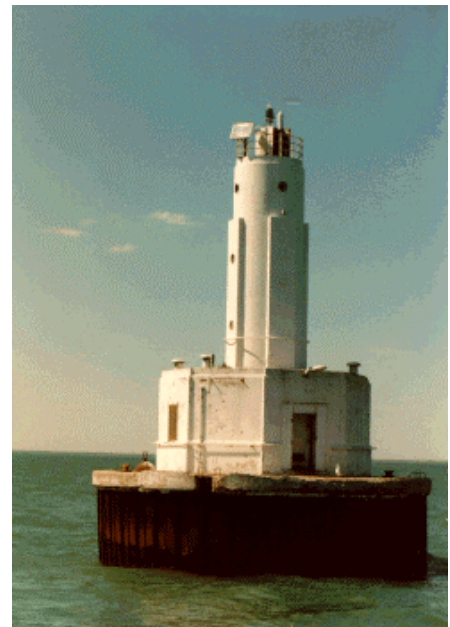
A U.S. Geological Survey report will be prepared in spring of 2001 to document the development process and the capabilities of the flow model. The model is expected to provide a basis for further studies of particle movements, water chemistry, and sediment transport within the waterway. An electronic version of the report and model input will be accessible for public information.

Development and on-going utilization of the flow model will depend on the continued availability of stage data at the model boundaries and interior points. In 1999, however, six of the gaging stations in the St. Clair – Detroit River waterway were targeted for elimination. Loss of these stations would have diminished the accuracy and limited extent to which the model could have been applied. Through the efforts of the Great Lakes Commission and other

organizations, however, funding was obtained to modernize the stations so that NOAA could effectively continue maintenance and operations.

Wind has a major effect on the circulation of water in Lake St. Clair, much like water-surface elevations control the movement of water within the connecting channels.

Continuous wind data for Lake St. Clair, however, is not currently available. One potentially suitable location for the establishment of a wind monitoring station is on the Lake St. Clair Lighthouse (pictured to the right). This



lighthouse is situated near the middle of the lake, just off the navigational channel in United States territorial waters. Such a station would provide data needed for this and other research activities on Lake St. Clair. Further, availability of this data in real time through the Internet would help improve the safety of recreational activities and commercial navigation on the Lake.

For Further Information:

To obtain information on the Source Water Assessment Program in Michigan, please contact

Wm. Elgar Brown, P.E.,

Water Bureau, Michigan Department of Environmental Quality,

525 W. Allegan

P.O. Box 30273

Lansing, MI 48909-7773 or

access the Internet at:

<http://www.michigan.gov/deqwd>



To obtain additional information on the development of the flow model, please contact

Dave Holtschlag

U.S. Geological Survey, 6520 Mercantile Way, Suite 5,
Lansing, MI 48911 or access the Internet at:

<http://mi.water.usgs.gov>

APPENDIX K

Michigan SWAP Water Table Mapping Protocol (November 2003)

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The reauthorization of the federal Safe Drinking Water Act (SDWA) of 1996 [P.L. 104-182, Section 1453 (a)] required federal guidance and defined state requirements for a source water assessment program (SWAP). These amendments required states to:

- Identify the areas that supply public tap water.
- Inventory contaminants and assess water system susceptibility to contamination.
- Inform the public of the results.

Michigan has almost 12,000 public water supplies (PWS) with over 18,000 sources. Of these, about 10,650 are noncommunity PWS with ground water as the source. These noncommunity, groundwater-based PWS include both transient and nontransient types:

- Schools (Nontransient)
- Businesses (Nontransient)
- Motels / Lodges (Transient)

A noncommunity PWS regulatory program has been operational within the Drinking Water Division of the Michigan Department of Environmental Quality (MDEQ) for many years. This noncommunity PWS program includes a sanitary survey of each system every five years, done through contracts with local health departments (LHDs).

Michigan's SWA Program builds upon this preexisting relationship with LHDs.

A new, on-site assessment protocol was developed for these sanitary surveys which included the:

- Capture the geographic location of the wellhead using GPS.
- Entry of the *water well and pump installation record* for the well into an electronic data management system called *Wellogis*.
- Determination of a Source Water Assessment Score (SWAS) that reflects the "inherent vulnerability" of the well and the source water.

This numeric system assigns points for situations that represent a "perceived risk" based on the evaluation of four criteria. The evaluation criteria provide a "qualitative assessment" of ground-water movement and the potential for movement of contaminants into the subsurface.

The Source Water Assessment Score is based on the evaluation of:

- The geologic sensitivity of the well ($SWAS_g$).
- The construction, maintenance and use of the system ($SWAS_w$).
- Chemistry and/or isotope data from the PWS well water ($SWAS_c$).
- Isolation of the PWS well(s) from sources of contamination ($SWAS_s$).

$$\text{SWAS} = \text{SWAS}_g + \text{SWAS}_w + \text{SWAS}_c + \text{SWAS}_s$$

Preliminary results, based on a sample of about 2000 noncommunity PWS, show:

- SWAS ranged from 0 (Great) to 205 (Bad)
- 24.4 % of the PWS ranked as having Low Susceptibility: $\text{SWAS} = 0 - 30$
- 63.8 % of the PWS ranked as having Moderate Susceptibility: $\text{SWAS} = 31 - 90$
- 11.8 % of the PWS ranked as having High Susceptibility: $\text{SWAS} > 90$

Although the potential and known sources of contamination were assessed during the SWA Scoring process (the SWAS_s score), several critical evaluation factors were not taken into account:

- 1) How deep is the water table (the receiving ground water for most contaminants, abandoned wells notwithstanding)?
- 2) Relative to the sources, is the water table sloping toward the well or away from the well?
- 3) What is the gradient of the water table?

These questions can be addressed using an interpolated water table map.

The water table mapping protocol developed for the Michigan SWA Project uses several different existing, digital, geospatial data sets. These include:

- Michigan Framework vector base map data digitized from U.S.G.S. 7.5-minute quadrangle maps. (http://www.dnr.state.mi.us/spatialdatalibrary/metadata/base24k_metadata.htm).
- Digital elevation data (DEM) – 7.5-minute, 30-meter postings. (http://rockyweb.cr.usgs.gov/elevation/dpi_dem.html) (<http://www.state.mi.us/webapp/cgi/mgdl/?rel=thext&action=thmname&cid=13&cat=Digital+Elevation+Model+%28DEM%29>)
- SSURGO or MIRIS digital soil data. (http://www.dnr.state.mi.us/spatialdatalibrary/metadata/SSURGO_metadata.htm).
- National Wetlands Inventory (NWI) digital data. (http://www.dnr.state.mi.us/spatialdatalibrary/metadata/NWI_Data.htm).

Step 1. Surface Hydrography

- A. Extract the perennial streams and lakes from the Michigan Framework Base Map data set (Figure 1). These vector data are then intersected with the DEM data (Figure 2) to extract all those DEM grid cells (30 x 30 meters) that contained a perennial hydrographic feature. The centroids of these grid cells were subsequently extracted; their elevation attribute is set to the DEM cell value.

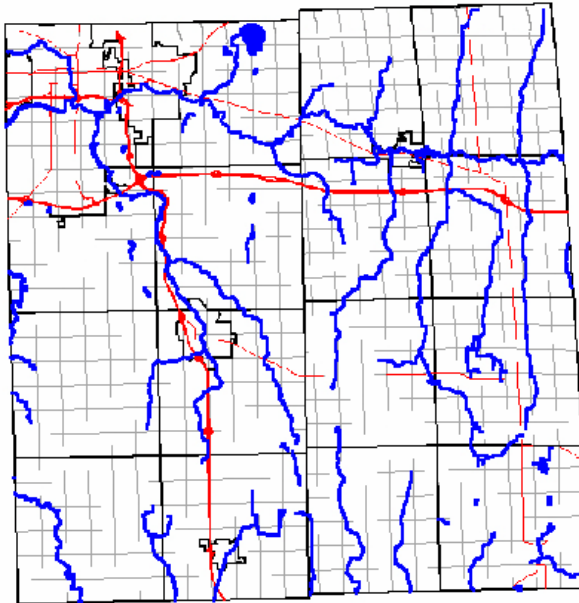


Figure 1. Perennial hydrography in Ingham County from Michigan Framework Data.

- B. Extract the intermittent streams and drains from the Michigan Framework Base Map data set (Figure 3). These vector data are then intersected with the DEM data (Figure 2) to extract all those DEM grid cells (30 x 30 meters) that contained an intermittent hydrographic feature. The centroids of these grid cells were subsequently extracted; their elevation attribute is set to the (DEM cell value – 6.5 feet). This is an arbitrary depth setting, but it was chosen for two reasons: 1) to be below the soil data in order to avoid overweighting these spots in the landscape; and 2) to ensure that the valley form of the intermittent features would be represented in the point data set, something that is less likely in the raw 30 x 30 meter DEM data

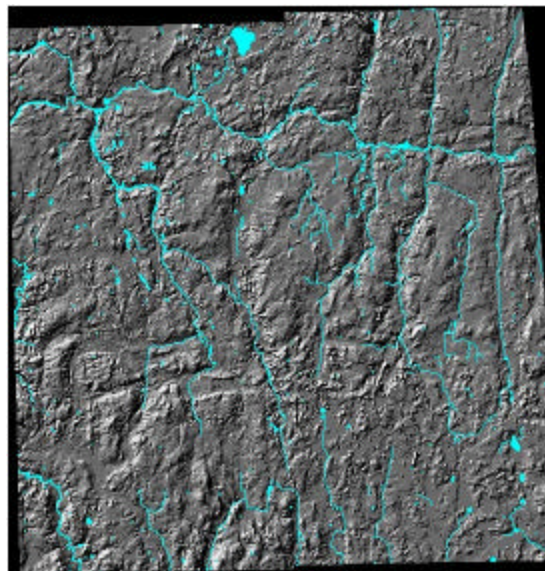


Figure 2. Hillshade presentation of the Ingham County 30-meter DEM.

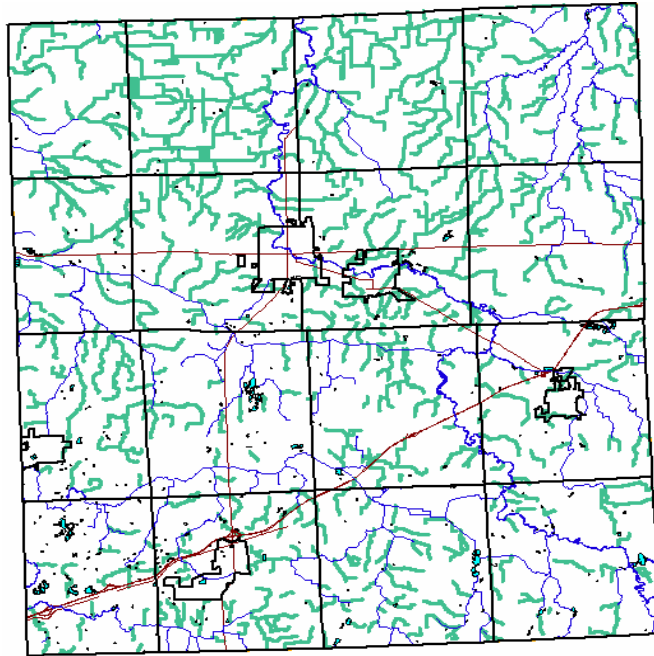


Figure 3. Intermittent hydrography in Shiawassee County from Michigan Framework Data. Thick (green) lines = intermittent features; thin (blue) lines = perennial features.

Step 2. Near-surface Water Table Observations.

- A. Process the SSURGO soil data, if available; otherwise the NWI data are used (see Step 2B). The SSURGO soils database contains information about the nature and depth of the seasonally high water table. The field **wtkind** contains information about whether the water table data refers to **perched** or **apparent** conditions (NRCS refers to the non-perched water table as “apparent”). All soil map units where “**wtkind** = apparent” are extracted from the data set. These vector polygons are rasterized at a 30-meter spacing to match the DEM data and the grid centroids (i.e., point data) are extracted (Figure 4). In addition to the surface elevation Z-value which they inherit from the DEM grid cell, each of these points receives an additional attribute from the field **wtdeph** that contains the maximum value for the range in depth to the seasonally high water table during the months specified. These data from the **wtdeph** field (i.e. the deepest water table depth) were selected in order to capture a mid-growing-season record of the depth to the water table. The final attribute used for subsequent processing is the subtraction of these two attributes: Soil Point Value = [(DEM_Value) – (**wtdeph**_value)].

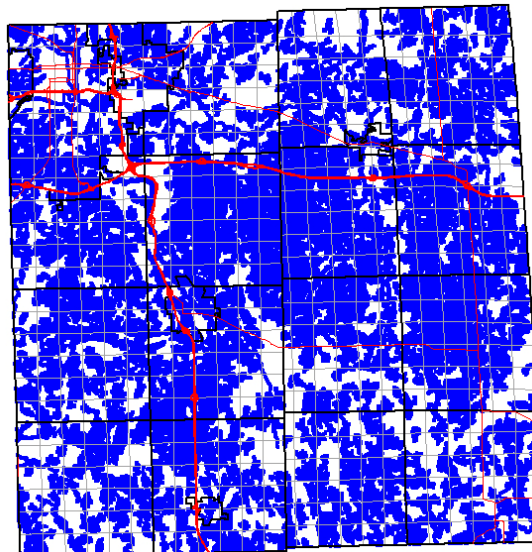


Figure 4. Points (30-meter spacing) extracted from SSURGO soils data recording the depth to the water table.

- B. If SSURGO data are unavailable, the NWI wetlands data are processed. All NWI polygons where **System** = "Palustrine" in the database are extracted. These vector polygons are rasterized at a 30-meter spacing to match the DEM data and the grid centroids (i.e. point data) are extracted (Figure 5). The surface elevation Z-value that they inherit from the DEM grid cell is reduced by 1.0 foot to create an approximated water table depth. This constant was determined by a test that overlaid all the NWI Palustrine polygons onto the SSURGO soils data in four selected counties in Michigan. The percentage of the coincident areas (i.e., palustrine wetland *and* SSURGO map unit where **wtkind** = apparent), by water table depth, is shown in the table below.

wtdeph value	Antrim County	Ingham County	Kent County	Monroe County
0 ft.	9.05 %	-	9.03%	58.37%
1 ft.	71.35%	68.97%	63.68%	13.86%
2 ft.	10.61%	17.27%	24.99%	17.22%
3 ft.	2.37%	8.54%	1.14%	4.58%
5 ft.	-	-	1.16%	-
6 ft.	6.62%	5.22%	-	5.97%

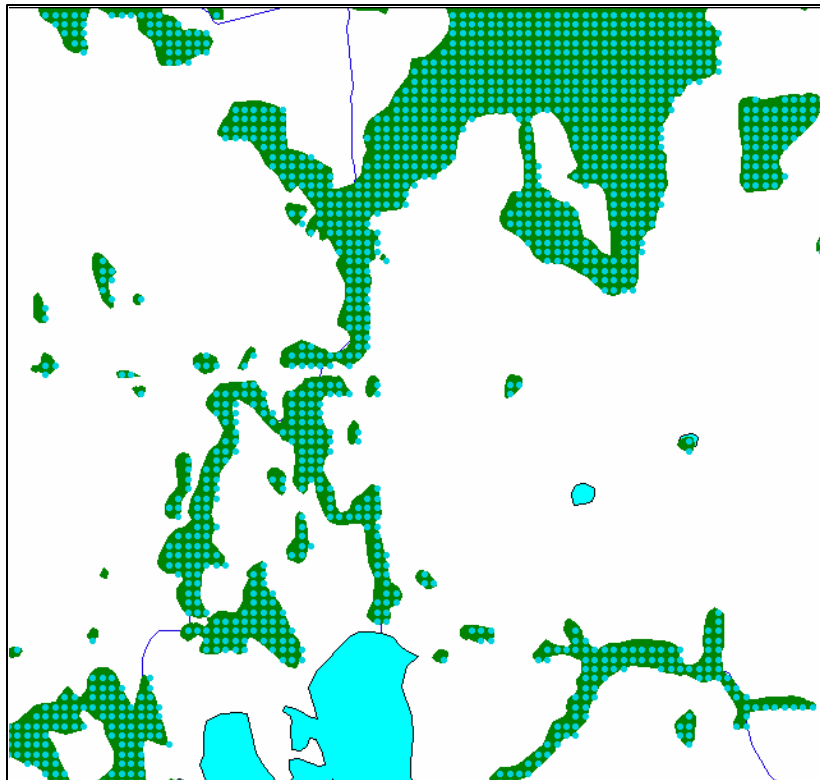


Figure 5. Points (30-meter spacing) extracted from the palustrine polygons in the National Wetlands Inventory data (2 sq. mile area from Bennington Twp., Shiawassee County).

SSURGO soils data from NRCS and non-SSURGO-certified digital soil data from MIRIS were used in this project. Combined, these two sources of digital soil data were available for 50 of the 83 counties of the state (Figure 6). For the remaining 33 counties, National Wetland Inventory (NWI) data were used.

Michigan Source Water Assessment Program

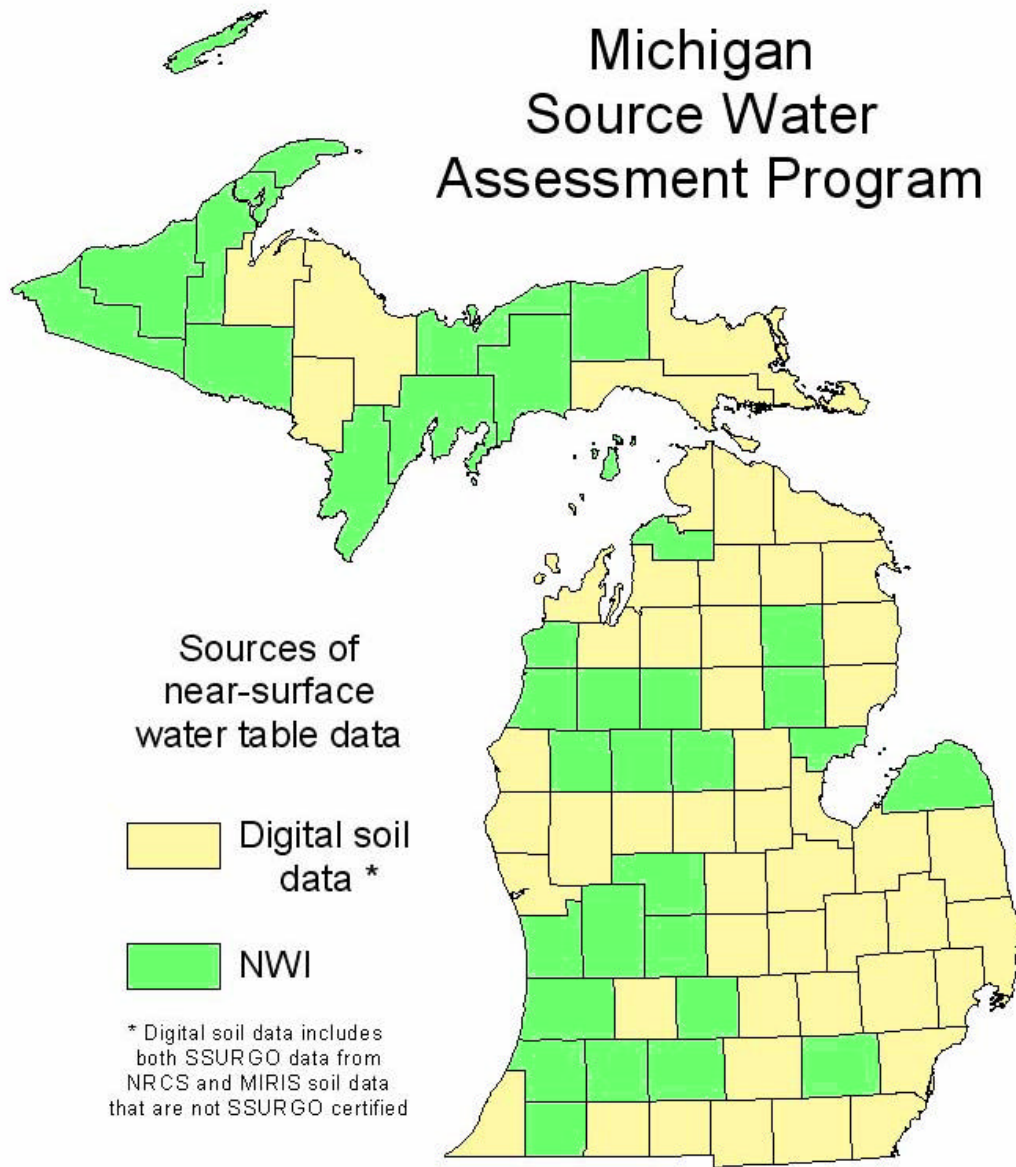


Figure 6. Sources of near-surface water table data.

Step 3. Merged Point File Creation and Water Table Interpolation.

The three point files from steps 1 and 2 are merged (Figure 7). These data are submitted to Kriging interpolation using the *Surfer* software program from Golden Software, Inc. This interpolation generates a water table elevation for each point in a regular grid of points spaced 30 meters apart across the whole county (Figure 8).

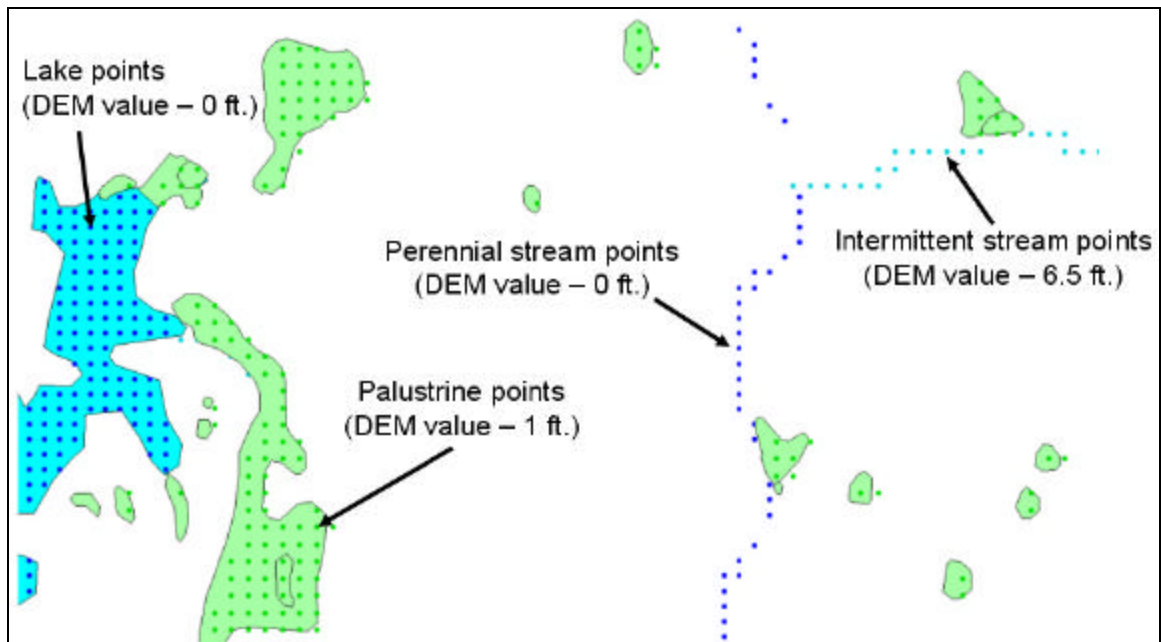
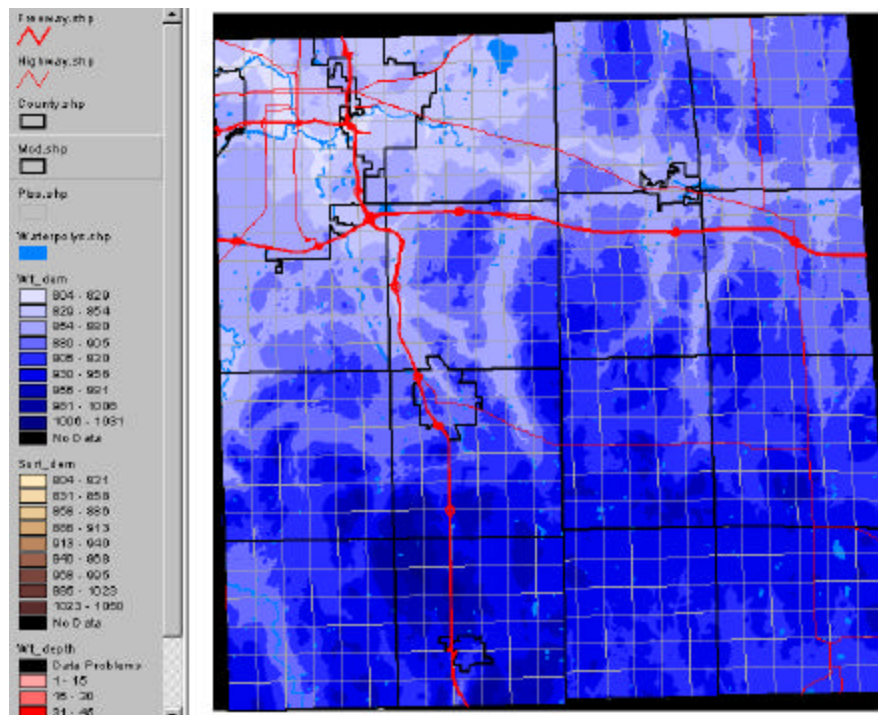


Figure 7. Merged file of water-table points from surface hydrography and NWI data.



Step 4. Depth to the Water Table

The 30-meter, water-table surface grid is subtracted from the 30-meter DEM surface to calculate the depth to the water table (Figure 9).

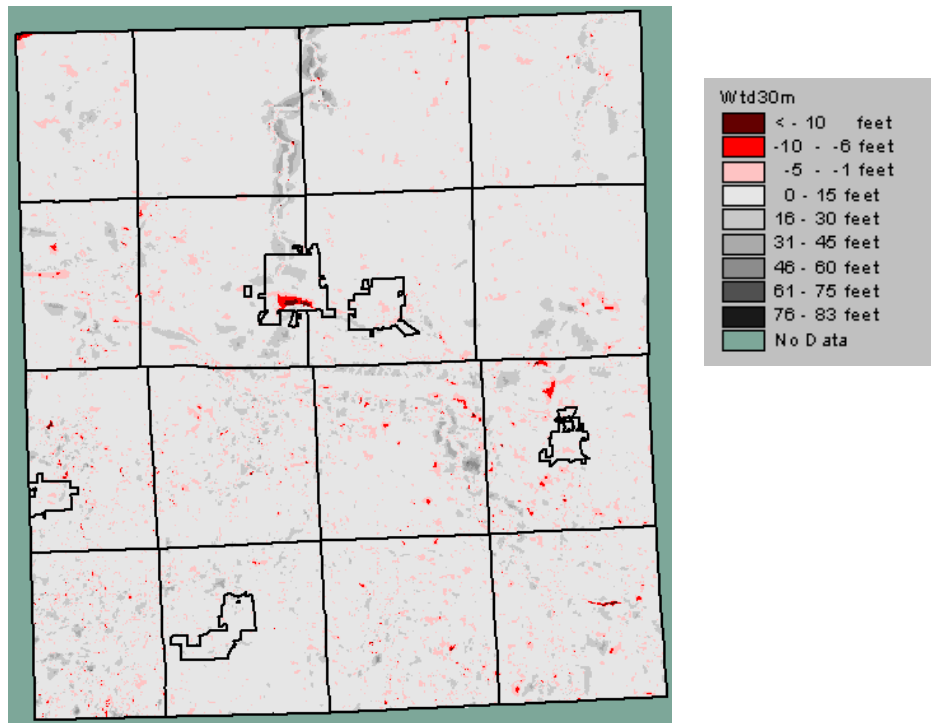


Figure 9. Interpolated depth to the water table, classed in 15-foot ranges.

Step 5. Isoline Presentation of Water Table Surface.

A second water-table surface using a 90-meter grid spacing is interpolated using linear Kriging. These raster data are then converted into isoline contours (using a 10 ft. contour interval), in order to better portray the gradient and direction of flow on the water table surface (Figure 10). The contours generated from the 90-meter water-table surface are smoother with fewer irregularities in comparison to those that can be generated from the 30-meter water-table surface.

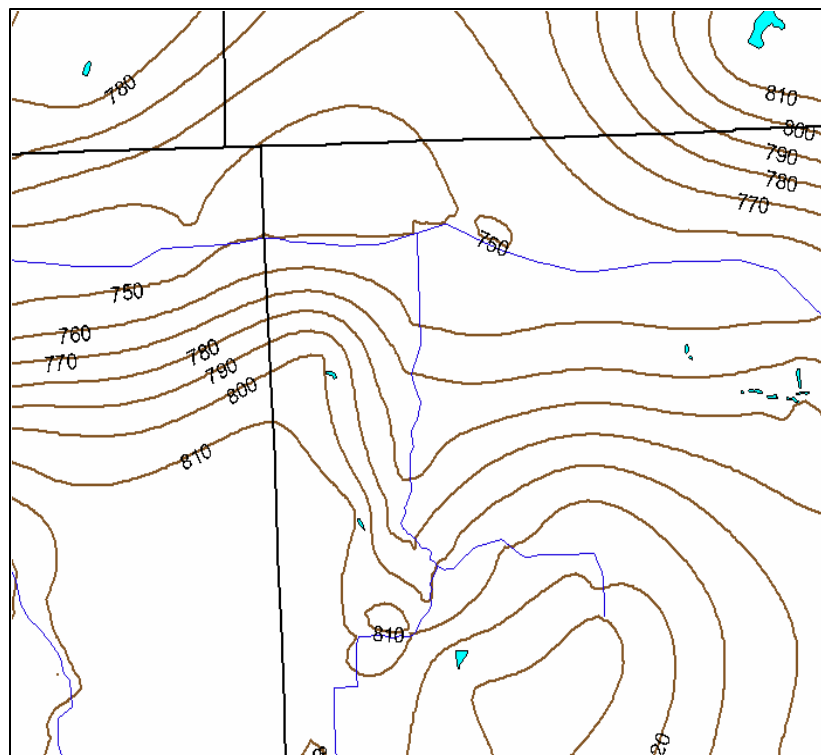


Figure 10. Isoline presentation of the interpolated water table surface (10 ft contours).

APPENDIX L

Michigan MapImage Viewer

The Michigan MapImage Viewer is a GIS software program that provides geographic data and mapping capabilities in a low-cost, easy-to-use format.

The Data:

The Michigan MapImage Viewer comes with a collection of data including the Michigan Geographic Framework data, the statewide collection of [MSU LandScan CD aerial images](#), topographic maps and other GIS data and digital imagery from the MDNR, MDEQ and federal sources. Additionally, the Viewer allows the user to customize the product by importing map files, digital imagery, and point data from coordinate files.

The Functionality:

The Michigan MapImage Viewer provides a set of mapping functions to find, display, measure, identify and query map features. A point-digitizing tool can be used to capture the geographic location (Latitude/Longitude) of selected points. The user can click on a map location to display LandScan aerial photos of the surrounding area. Image controls include a magnifying glass, image enhancement functions, zoom map to active photo and image annotation tools for drawing text, lines, symbols and other graphic objects.

Effective July 1, 2004, the Michigan MapImage Viewer software, developed at Michigan State University (MSU) [Remote Sensing and GIS](#), is being distributed and supported by [GeoPathway LLC](#). The MSU license agreement allows GeoPathway to reproduce, sell and distribute the MapImage Viewer products, make derivatives, and to sub license the product and product derivatives to third parties. GeoPathway will provide technical support to the end-user community and continue to develop new versions of the software.

MSU RS&GIS will continue to provide Michigan MapImage Viewer training and undertake MapImage Viewer research and development projects. Current RS&GIS MapImage Viewer projects include:

- **Critical Dune Management**

A GIS decision support tool is being built within the MapImage Viewer to help Michigan Department of Environmental Quality staff assess and manage critical dune areas in Michigan. For a proposed dune development site, the viewer searches data themes to collect site information and extract soils database information and topographic data (including LIDAR elevation values).

- **Statewide Groundwater Mapping**

RS&GIS is developing new MapImage Viewer functions and related software to analyze the lithology information (strata formations) on water well records to assist MSU, USGS, and MDEQ scientists who are compiling a statewide groundwater inventory and constructing a groundwater aquifer map of Michigan.

- **Health Impact Assessment**

New site analysis protocols and GIS tools are being developed and integrated with existing and new geospatial data to construct a Health Impact Assessment (HIA) tool for reviewing proposed land development site plans. The HIA tool can be used by local and regional planners to evaluate current development project plans based on their impact on community health. The HIA tool will be pilot-tested with local planning bodies in the Tri-County area of Ingham, Clinton, and Eaton counties.

- **Source Water Protection**

MapImage Viewer Custom tools are being developed to facilitate source applications of GIS technology and water protection planning by the MDEQ, local health departments, water suppliers and the communities they serve. RS&GIS is also providing training and technical assistance to the MDEQ and several pilot County Health Departments that are using the MapImage Viewer Network Edition

More Information:

- Contact us at mapimage@rsgis.msu.edu.
- Order individual copies of the [Michigan MapImage Viewer](#).
- You will be redirected to the Geopathway LLC website: <http://www.geopathway.com/>
- Geopathway LLC is licensed by MSU to sell, distribute, support, and develop new versions of the Michigan MapImage Viewer.

APPENDIX M

Community Water Supplies Using Surface Water

● Dots show water intake location



APPENDIX N

ACRONYMS

Act 368 – Groundwater Quality Control Act 1978, P.A. 368, as amended, and rules.

BASINS – Better Assessment Science Integrating point and Nonpoint Sources

CAZ – Critical Assessment Zone

CCM – Continuous Confining Material

CPCM – Continuous Partially Confining Material

CPWS - Community Public Water Supply

DEM – Digital Elevation Models

DRG – Digital Raster Graphics

ESRI – Environmental Systems Research Institute, Inc.

GEM - Groundwater Education in Michigan

GIS – Geographic Information System

GLNPO – Great Lakes National Program Office

GPM – Gallons Per Minute

GPS - Global Positioning System

ICR – Information Collection Rule

IFD – Industrial Facilities Discharge

in/hr – Inches Per Hour

KHS – Karst Hydrologic Systems

LHD - Local Health Department

MCL - Maximum Contaminant Level

MCLG – Maximum Contaminant Level Goal

MDEQ - Michigan Department of Environmental Quality

MSU - Michigan State University

NCPWS - Noncommunity Public Water Supply

NPL – National Priority List

NPRI – National Pollutant Release Inventory

NRCS – National Resources Conservation Service

PAC – Public Advisory Committee

PCS – Potential Contaminant Source

PCSD – Permit Compliance System Database

PWS – Public Water Supply

RCRIS – Resource Conservation and Recovery Information System

RF3 – River Reach files

SDWA - Safe Drinking Water Act

SGBD – Statewide Groundwater Data Base

SOC – Synthetic Organic Compounds

STATSGO – State Soil and Geographic

SWA – Source Water Area

SWAP - Source Water Assessment Program

SWAS - Source Water Assessment Score

SWAS_C – Score for chemistry and isotope data

SWAS_G – Sum of a geologic sensitivity score

SWAS_S – Isolation and control from sources of contamination score

SWAS_W – Well construction score

TAC – Technical Advisory Committee

TMDL – Total Maximum Daily Loads

TOT - Time-of-Travel

TRI – Toxic Release Inventory

USEPA - United States Environmental Protection Agency

USGS - United States Geological Survey

VOC – Volatile Organic Compounds

WHPA - Wellhead Protection Area

WHPP - Wellhead Protection Program

WTP – Water Treatment Plant